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SOLAR-PIEZO HYBRID CHARGING SYSTEM

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Abstract— **The Solar-Piezo Hybrid Power Charging System is a sustainable, smart energy solution designed to harness power from both solar and mechanical vibration sources. This hybrid system uses a solar panel producing between 12V to 18V and a piezoelectric transducer generating approximately 0.5V from mechanical pressure (e.g., human footsteps or environmental vibrations). The piezoelectric signal is rectified through a bridge rectifier and both energy sources feed into a common battery for storage. A voltage sensor continuously monitors the battery level and sends this data to a NodeMCU (ESP8266) microcontroller. The system uses a DC to AC inverter and a step-up transformer to convert the stored DC voltage into a usable 230V AC output, making it suitable for powering standard electrical appliances via a socket. Additionally, the NodeMCU facilitates real-time monitoring through IoT (Internet of Things) integration, sending system data via Wi- Fi and displaying live output values and battery status on an LCD screen. This makes the system not only energy efficient but also smart and user-friendly. This hybrid model demonstrates how renewable energy from both sunlight and mechanical motion can be effectively utilized for reliable power generation, making it suitable for remote areas, emergency power supplies, and smart home applications.**

Keywords— **Piezo electric plates, Solar panel, Bridge rectifier, Node MCU, LCD display, Inverter circuit, Battery, Pocket IOT, Socket.**

I. INTRODUCTION

A. INTERNET OF THINGS

The Solar-Piezo Hybrid system represents a significant advancement in renewable energy technology by integrating two complementary energy harvesting methods-solar power and piezoelectricity-into a single, efficient solution. Solar energy, harnessed through photovoltaic (PV) panels, is a well-established and clean source of electricity, especially effective in regions with abundant sunlight. These panels convert sunlight directly into electrical energy via the photovoltaic effect, providing a substantial and reliable power source during daylight hours. However, solar energy is inherently intermittent, with its output fluctuating based on weather conditions and the time of day, which can limit its effectiveness as a sole energy provider. To address this limitation, the hybrid system incorporates piezoelectric materials, which generate electricity from mechanical stress, such as vibrations or pressure. This technology leverages the piezoelectric effect; wherein certain materials produce an electric charge in response to applied mechanical force. In practical applications, piezoelectric sensors can be embedded in high-traffic areas like walkways, roads, or urban environments to capture the otherwise wasted kinetic energy from footsteps, vehicles, or machinery. By combining these two energy sources, the Solar-Piezo Hybrid system ensures continuous energy generation, even when one source is less active. For instance, during cloudy days or nighttime, when solar output drops, the system can still produce electricity from ambient vibrations and movement, thereby enhancing overall energy reliability and efficiency. Central to this hybrid approach is an intelligent energy management system that optimizes the collection, storage, and distribution of harvested energy.

SCOPE AND OBJECTIVES

The objective of the solar-piezo hybrid charging system is to develop an efficient and sustainable energy harvesting solution that combines solar photovoltaic (PV) power with piezoelectric energy generation to charge batteries or power small electronic devices. By integrating these two renewable energy sources, the system aims to maximize energy collection under varying environmental conditions, ensuring continuous power availability even when sunlight is insufficient, such as during cloudy weather or nighttime. The system is designed to enhance overall energy output, improve harvesting efficiency through optimized circuitry, and provide a reliable, eco-friendly alternative to conventional power sources. This hybrid approach not only promotes the use of green energy but also expands the potential for applications in remote or portable systems where consistent and self-sustaining power is essential.

II. SYSTEM DESCRIPTION

The solar-piezo hybrid charging system is a combined energy harvesting setup that utilizes both solar photovoltaic (PV) panels and piezoelectric transducers to generate electrical power. The solar panel converts sunlight into direct current (DC) electricity, while the piezoelectric transducers convert mechanical vibrations or pressure (such as from foot traffic, machinery, or environmental movement) into electrical energy. Both energy sources are connected to a power management circuit, typically including a bridge rectifier for the piezoelectric AC output, a voltage regulator, and a charge controller to manage the flow of electricity into a rechargeable battery or storage unit. The system ensures that energy from both sources is efficiently combined and stored, providing a stable power supply for various low- power applications such as sensors, portable electronics, or emergency backup systems. This hybrid approach improves the reliability and efficiency of renewable energy harvesting by taking advantage of two complementary sources, making it especially useful in areas where sunlight is inconsistent or where mechanical energy is readily available.

III. BLOCK DIAGRAM

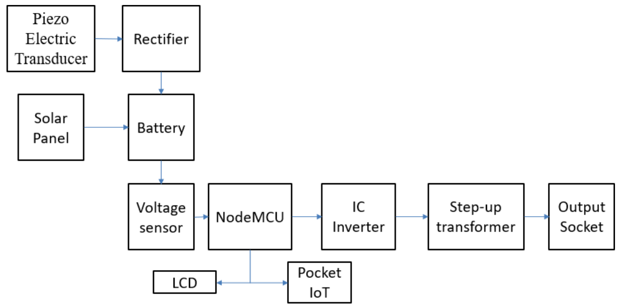
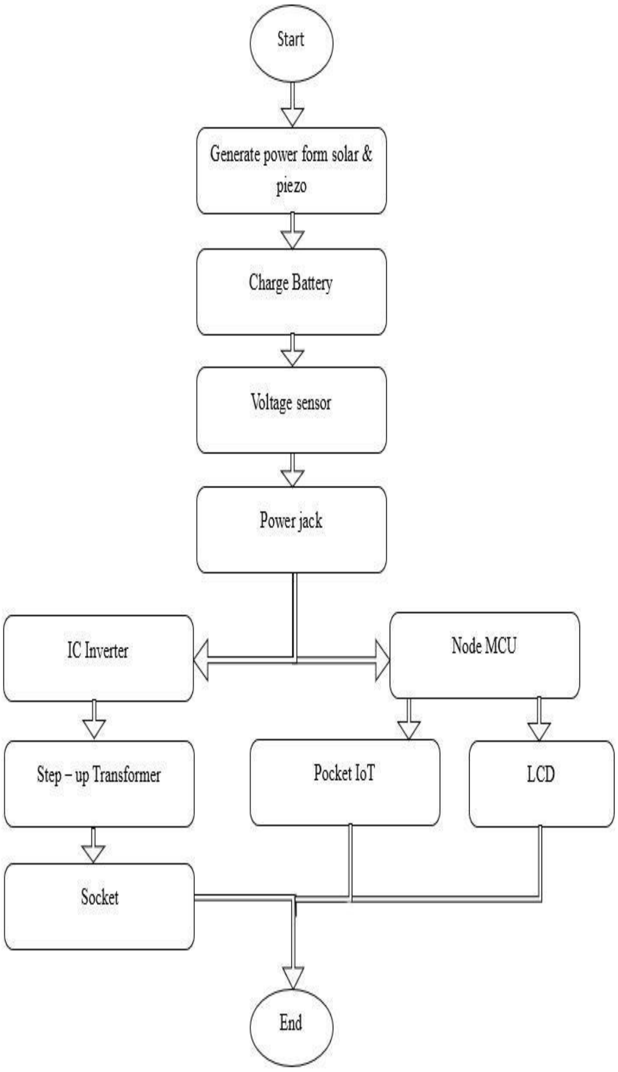


Fig. 1. Block Diagram of proposed system

The system integrates piezoelectric and solar energy sources for hybrid power generation. A piezoelectric transducer generates AC power from mechanical vibrations, which is then converted into DC by a rectifier. Simultaneously, a solar panel provides additional DC power to charge a common battery. This battery serves as the main energy storage unit. A voltage sensor is used to monitor the battery levels in real time. The NodeMCU microcontroller processes this sensor data and sends it to the Pocket IoT platform for remote monitoring. Additionally, an LCD displays the system status locally for user convenience. The stored DC power in the battery is converted into AC using an IC inverter. A step-up transformer is used to boost the AC voltage to a usable level. Finally, the power is made available through an output socket for operating external devices.

IV. FLOW CHART



V. RESULTS & DISCUSSIONS

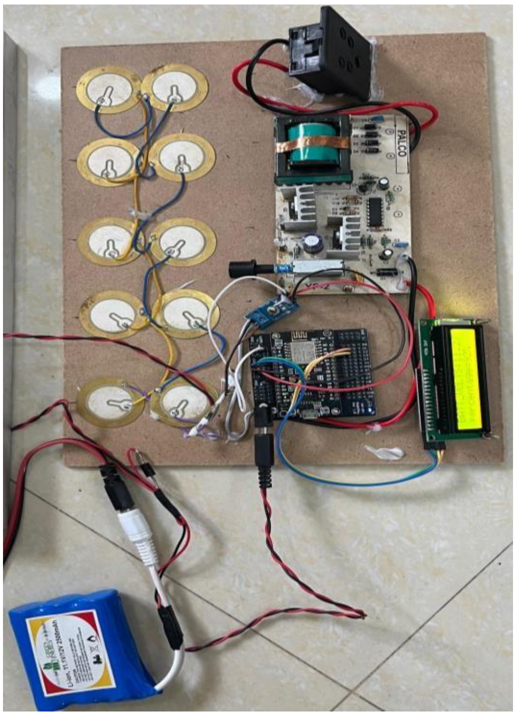
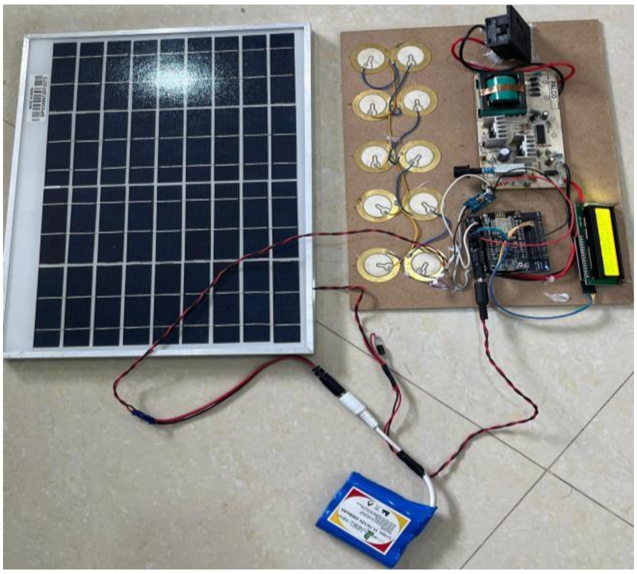


Fig. 2. Proposed model of piezo charging system- Stage 1

The above figure shows the piezoelectric charging system successfully converted mechanical vibrations into electrical energy, producing a measurable output voltage from the piezoelectric discs. The generated AC voltage was effectively rectified into DC by the bridge rectifier and regulated to a stable voltage level suitable for charging a storage device or powering low-power electronics like the ESP8266 and LCD. The output voltage and current varied with the intensity and frequency of mechanical input, demonstrating the system's ability to harvest energy under different conditions. Overall, the system provided a consistent and usable electrical output, confirming its effectiveness in energy harvesting applications.

Fig. 3. Proposed model of Solar Piezo Charging System – Final Stage



The above figure shows Upon successful development and testing, the hybrid system demonstrated reliable power generation from both solar and piezoelectric sources under varying environmental conditions. When exposed to sunlight, the solar panel efficiently charged the battery, with the Node MCU accurately reporting voltage and current values to the cloud. During periods of rainfall or mechanical impact, the piezoelectric transducer generated measurable voltage, supplementing the energy harvested by the solar panel. The system's ability to switch between energy sources based on real-time sensor feedback ensured continuous charging, even during adverse weather conditions.

CONCLUSION

In conclusion, the solar-piezo hybrid power charging system demonstrated enhanced energy harvesting, improved reliability, and effective remote monitoring through Node MCU integration. The system is particularly suited for locations where both sunlight and mechanical vibrations are available, such as walkways, transportation hubs, or remote monitoring stations. Future work could focus on optimizing piezo array placement, improving power conversion efficiency, and incorporating machine learning algorithms for predictive maintenance and adaptive energy management. This project highlights the potential of hybrid renewable systems in advancing sustainable and intelligent energy solutions. In practical terms, this system can be deployed in remote areas, smart cities, or as part of portable charging solutions for emergency scenarios. The modular design allows for future expansion, such as integrating additional sensors or advanced energy management algorithms. Further improvements could include optimizing the power electronics for higher efficiency, incorporating machine learning for predictive maintenance, and enhancing security for IoT data transmission. Overall, this hybrid approach represents a significant step toward sustainable, intelligent, and adaptable energy solutions for the future.

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